

RD-A153 374

ON THE STRESS ANALYSIS OF BONDED INSERTS(U)  
AERONAUTICAL RESEARCH LABS MELBOURNE (AUSTRALIA)

1/1

R JONES ET AL. JUL 84 ARL/STRU-487

UNCLASSIFIED

F/G 20/11

NL

END  
FILED  
DTIC



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

ARL-STRUC-R-407

AR-003-941



AD-A153 374

DEPARTMENT OF DEFENCE  
DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION  
AERONAUTICAL RESEARCH LABORATORIES

MELBOURNE, VICTORIA

STRUCTURES REPORT 407

ON THE STRESS ANALYSIS OF BONDED INSERTS

by

R. Jones and M. Heller

THE UNITED STATES NATIONAL  
TECHNICAL INFORMATION SERVICE  
IS AUTHORISED TO  
REPRODUCE AND SELL THIS REPORT

APPROVED FOR PUBLIC RELEASE

S E L E C T E D  
MAY 9 1984  
JULY 1984

© COMMONWEALTH OF AUSTRALIA 1984

COPY NO

JULY 1984

85 5 09 290

AR-003-941

DEPARTMENT OF DEFENCE SUPPORT  
DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION  
AERONAUTICAL RESEARCH LABORATORIES

STRUCTURES REPORT 407

**ON THE STRESS ANALYSIS OF BONDED INSERTS**

by

R. Jones and M. Heller

**SUMMARY**

*Recent experimental work has shown that adhesively bonded inserts can significantly increase the fatigue life of fastener holes. This paper concentrates on developing an understanding of the mechanisms which give rise to the observed increase in life. Cracked as well as uncracked fastener holes are considered. It is shown that both the stress concentration factors, and the stress intensity factors are significantly reduced by the use of either bonded rivets or bonded sleeves. It is also shown that the stress intensity factor, for a cracked hole repaired by a bonded insert, can be obtained by analogy with readily available solutions.*



---

POSTAL ADDRESS: Director, Aeronautical Research Laboratories,  
Box 4331, P.O., Melbourne, Victoria, 3001, Australia

## **CONTENTS**

**Page No.**

### **NOTATION**

### **1. INTRODUCTION**

1

### **2. METHOD OF ANALYSIS**

1

**2.1 Determination of Stress Intensity Factor**

2

**2.2 Modelling of Thin Adhesive Layer**

2

**2.3 Adhesive Failure**

2

### **3. NUMERICAL INVESTIGATION**

2

**3.1 Bonded Rivet**

3

**3.1.1 Specimen 1: Un-cracked**

3

**3.1.2 Specimen 1: Cracked on One Side**

3

**3.1.3 Specimen 1: Cracked on Both Sides**

3

**3.1.4 Specimen 2: Cracked on One Side**

3

**3.2 Bonded Sleeve**

3

### **4. DISCUSSION**

4

**4.1 Un-cracked Specimen**

4

**4.2 Cracked Specimen**

4

**4.3 Experimental Results**

4

### **5. CONCLUSION**

4

### **6. ACKNOWLEDGEMENT**

5

A1



**REFERENCES**

**TABLES**

**FIGURES**

**DISTRIBUTION LIST**

**DOCUMENT CONTROL DATA**

## NOTATION

<i>a</i>	Length of crack in specimen
<i>E</i>	Modulus of elasticity
<i>K</i>	Mode I stress intensity factor
<i>r</i>	Distance from crack tip
<i>t</i>	Adhesive thickness
<i>u</i>	Displacement of point on crack face at distance <i>r</i> from crack tip
<i>v</i>	Poisson's ratio
<i>x,y</i>	Cartesian co-ordinate axes system
<i>σ</i>	Remote stress applied to specimen
<i>θ</i>	Angular rotation from <i>x</i> axis

## **1. INTRODUCTION**

This report describes work done as part of the continuing fatigue-life enhancement program at the Aeronautical Research Laboratories, Australia. In the past, considerable effort has been spent on developing adhesively bonded repairs to aircraft structural components. One area of particular importance is the fatigue life enhancement of fastener holes, since these are common sites for fatigue crack initiation in aircraft structural components.

In recent years a new method has been proposed for the fatigue-life enhancement of fastener holes [1, 2]. This approach involves bonding an insert, either a fastener or a sleeve, into the fastener hole. The idea is based on the premise that the adhesive improves the load transfer in the component, thereby reducing the stress concentrating effect of the hole, and subsequent to crack initiation, reduces the stress intensity factor at the crack tip. Experimental work has shown that this method significantly reduces the rate of fatigue crack propagation from fastener holes, and is superior to other life enhancement schemes [2].

Analytical solutions for the stress analysis of fastener holes with bonded inserts are not available, due to the geometric complexity and material discontinuity occurring in such components. This necessitates the use of either numerical or experimental methods for the study of this class of problem.

In this report we carry out stress analyses of fastener holes with bonded inserts (both rivets and sleeves) by using the finite element method [3, 4], with fracture mechanics [5, 6] playing a key role. The influence of variations in both adhesive thickness and crack length are considered in detail.

In Section 2, a background to the finite element method used is given. This is followed in Section 3 by numerical investigations of single hole specimens with bonded rivets and bonded sleeves. The results are then discussed in Section 4.

## **2. METHOD OF ANALYSIS**

In this paper, we carry out elastic stress analyses of cracked and uncracked specimens, to investigate the effects of bonded inserts, using the finite element method. For uncracked specimens, the stress concentrating effect of the hole is particularly important, since this governs the time to crack initiation, while for cracked specimens, the stress intensity factor is of key importance, since this governs the rate of fatigue crack propagation.

To carry out the stress analysis using finite element methods, three complications need to be addressed, namely,

- (i) correct modelling of the crack tip displacement singularly, to allow the stress intensity factor to be determined,
- (ii) modelling of the very thin adhesive layer, and
- (iii) consideration of the possibility of adhesive failure.

## 2.1 Determination of Stress Intensity Factor

A number of finite element methods can be used to model two-dimensional crack-tip behaviour. The best of these methods are reviewed in references [7] and [8]. We use small triangular isoparametric elements at the crack tip, with their mid-side nodes shifted to the quarter point [9]. These elements give the required  $r^{1/2}$  displacement singularity, are accurate, and are easy to implement. Thus, from near tip displacements, the stress intensity factor is determined using the equation given in reference [5], namely

$$K = \frac{uE}{4(1-\nu^2)} \sqrt{\frac{2\pi}{r(1+r/2l)}} \quad (2.1)$$

where  $u$  is the displacement of a point on the crack face,  $r$  is the distance of that point from the crack tip and  $l$  is the crack half length as defined in reference [5].

## 2.2 Modelling of Thin Adhesive Layer

In the analysis of fasteners with bonded inserts, it is apparent that the thickness of the adhesive is very small compared with characteristic values of hole radii. This necessitates the use of high aspect ratio elements to model the adhesive, if unduly refined element meshes in the rest of the structure are to be avoided. In modelling the adhesive, eight-noded isoparametric elements are used and to overcome the problems associated with high aspect ratio elements, reduced integration is used, and the stiffness matrices are computed using double precision. The problems associated with the use of high aspect ratio elements are discussed in detail in reference [10].

## 2.3 Adhesive Failure

In the majority of the work done in this investigation, it was assumed that the adhesive remained intact with no adhesive failure criterion being adopted. However, some analyses were done using a simplistic approach, whereby the adhesive was allowed to debond over 50% of the contact area with the specimen, as shown in Figure 1.

## 3. NUMERICAL INVESTIGATION

Detailed finite element analyses of typical single-holed tension specimens were done to investigate the possible benefits of using bonded inserts as a life enhancement method. The geometry of these specimens was chosen so as to coincide with those for which test results are given in reference [2]. Both cracked and uncracked specimens were considered, and the effects of variation in adhesive thickness and crack length were studied. The analyses were done using the PAFEC suite of programs on the ARL VAX 11/780 computer. The finite element stiffness matrices were computed using reduced integration and double precision and the solution was performed using double precision.

The analyses of two different specimens, which we designate No. 1 and No. 2, were undertaken for elastic plain-strain conditions, and these are shown in Figure 2. Both specimens were loaded by a remote tension stress of 265 MPa, and are aluminium alloy, with the material properties  $E = 73$  GPa and  $\nu = 0.32$ . For all cases, the adhesive material properties were taken as  $E = 1.89$  GPa and  $\nu = 0.35$ .

Various analyses were conducted for specimens with both bonded rivets and bonded sleeves, and are discussed in detail in the following subsections. Stress intensity factors were determined using equation 2.1.

### **3.1 Bonded Rivet**

For all cases discussed, the rivet is aluminium alloy, with material properties  $E = 73$  GPa and  $\nu = 0.32$ . Also for comparison purposes, some analyses were done without the rivet, and some with the glue allowed to fail in tension (as explained in Section 2.3).

#### **3.1.1 Specimen 1: Uncracked**

Specimen 1 was first considered to be uncracked. Due to symmetry only 1/4 of the structure was modelled, as shown in Figure 3. The resultant finite element mesh consisted of 38 eight-noded isoparametric quadrilateral elements, and 8 six-noded isoparametric triangular elements. The values of the maximum principal stress in the specimen are given in Table 1.

#### **3.1.2 Specimen 1: Cracked on One Side**

Here the specimen was considered with a crack along its centreline, emanating from the hole edge, as shown in Figure 4a. Due to symmetry only 1/2 of the structure was modelled, as shown in Figure 5. The resultant finite element mesh consisted of 74 eight-noded isoparametric quadrilateral elements, and 34 six-noded isoparametric triangular elements. The results for stress intensity factors at the crack tip are given in Table 2. Further analyses were also done with the rivet rigidly attached to the specimen, this being equivalent to the specimen being cracked, but having no hole. These results are also given in Table 2.

#### **3.1.3 Specimen 1: Cracked on Both Sides**

In this case the specimen was considered with symmetric cracks along its centreline, emanating from the hole edge, as shown in Figure 4b. Due to symmetry only 1/4 of the structure was modelled. The finite element mesh used was identical to that shown in Figure 5, except that the left half of the structure was omitted and nodes on the  $y$  axis were restrained in the  $x$  direction. The values of stress intensity factors are given in Table 3.

#### **3.1.4 Specimen 2: Cracked on One Side**

Due to symmetry only 1/2 of the structure was modelled. The finite element mesh was identical to that used in Section 3.1.2, except that the structure was double that size. Stress intensity factors are given in Table 4.

### **3.2 Bonded Sleeve**

In this case the insert was a steel sleeve with the material properties,  $E = 210$  GPa and  $\nu = 0.32$ , and of 1 mm thickness. The structure modelled was specimen 2 with a crack on one side, emanating from the hole edge, as shown in Figure 4a. Due to symmetry only 1/2 of the structure was modelled, as shown in Figure 6. The resultant finite element mesh consisted of 78 eight-noded isoparametric quadrilateral elements and 23 six-noded isoparametric triangular elements. The results for stress intensity factors are given in Table 5.

## **4. DISCUSSION**

From the results of the numerical investigation in Section 3, a number of interesting trends have become evident, and are described in the following subsections.

### **4.1 Uncracked Specimens**

The results in Table 1 indicate that using a bonded rivet gives rise to a reduction in the maximum principal stress in the specimen of the order of 50%. This reduction is a maximum for the thinnest adhesive thickness, and decreases as the adhesive thickness is increased. When the adhesive is assumed to have failed by debonding over part of the interface the reduction in the stress level is approximately 40%.

### **4.2 Cracked Specimen**

There are a number of important points which arise from this analysis, viz.:

- (i) A bonded rivet or sleeve significantly reduces the stress intensity factor. This is true even after a significant proportion of the adhesive has failed.
- (ii) The values of the stress intensity factors for a crack on one side of a bonded rivet hole and for a crack of the same length, on both sides of the hole are very similar, as can be seen from Tables 2 and 3.
- (iii) From Table 2, by comparing the values in the 'No Hole' column with the other values, we see that as the crack length increases, a crack at a bonded rivet hole behaves very much as if the specimen does not contain a hole at all. For specimen 1 this asymptotic behaviour is effectively reached at a crack length of approximately 2.5 mm. This is particularly important since a hand-book solution is available for the 'No Hole' case [1]; it appears then that this solution could be conveniently used in some instances for estimating the stress intensity factor for a cracked hole containing a bonded insert.

### **4.3 Experimental Results**

The large reductions in the stress intensity factors indicated in our numerical investigation should give rise to a significant increase in the fatigue life of a specimen with an adhesively bonded insert. This effect has been confirmed in a companion paper [2], as can be seen from the experimental results given in Table 6, which deal with the life of specimen number 1 under a typical service-load spectrum.

## **5. CONCLUSION**

This paper has shown that the stress concentration factors at a hole and the stress intensity factors at a cracked hole are significantly reduced if the hole contains a bonded rivet or a bonded steel sleeve. It has been shown that, as the crack length increases, the solution for a cracked hole containing a bonded insert approaches that for a crack alone, i.e. with no hole in the specimen. For the latter case a hand-book solution is readily available.

The next stage of this project involves a joint numerical and experimental investigation into the repair of a quadrant crack emanating from a fastener hole.

#### **6. ACKNOWLEDGEMENT**

The authors wish to acknowledge the interest, and encouragement in this project given by  
Dr A. A. Baker of Materials Division, ARL.

## REFERENCES

- [1] Jones, R., and Callinan, R. J. 'New thoughts on stopping cracks which emanate from holes'. *Int. Jnl Fracture*, Vol. 17, 1981, pp. R53-R55.
- [2] Mann, J. Y., Bell, R. A., Jones, R., and Heller, M. 'The use of adhesive-bonded rivets to reduce the effects of rivet holes on fatigue life'. *ARL Structures Report 399*, 1984.
- [3] Zienkiewicz, O. C. 'The finite element method'. 3rd Ed., McGraw-Hill, New York, 1977.
- [4] Bathe, K. J. 'Finite element procedures in engineering analysis'. Prentice-Hall, 1982.
- [5] Liebowitz, H. 'Fracture: An advanced treatise'. Vols I-VII, Academic Press, New York, 1968.
- [6] Knott, J. F. 'Fundamentals of fracture mechanics'. Butterworths, London, 1973.
- [7] Fawkes, A. J., Owen, D. R. Y., and Luxmore, A. R. 'An assessment of crack tip singularity models for use with isoparametric elements'. *Engineering Fracture Mechanics*, Vol. 11, pp. 143-159, 1979.
- [8] Jones, R., Watters, K. C., and Callinan, R. J. 'A hybrid contour method'. *Jnl Structures and Mechanics* (in press).
- [9] Henshel, R. D., and Shaw, K. G. 'Crack tip elements are unnecessary'. *Int. Jnl Numerical Methods in Engineering*. Vol. 9, pp. 495-507.
- [10] Jones, R., and Callinan, R. J. 'Some thoughts on 3D isoparametric elements'. *ARL Structures Report 489*, 1983.
- [11] Rooke, D. P., and Cartwright, D. J. *A Compendium of Stress Intensity Factors*. Her Majesty's Stationery Office, London, 1976.

**TABLE 1**  
**Maximum Principal Stress for Uncracked Specimen No. 1 at  $\theta = 0$**   
**with Bonded Rivet**

Case Considered	Maximum Principal Stress MPa
<b>Unfilled hole</b>	853
<b>Bonded Rivet</b>	
$t = 0.0127 \text{ mm}$	337
$t = 0.0254 \text{ mm}$	387
$t = 0.0381 \text{ mm}$	456
<b>Bonded Rivet—</b>	
<b>Partial debonding of adhesive</b>	
$t = 0.0127 \text{ mm}$	427
$t = 0.0254 \text{ mm}$	483
$t = 0.0381 \text{ mm}$	580

$t$  = adhesive thickness

**TABLE 2**  
**Stress Intensity Factors for Specimen No. 1 Cracked on One Side**

Crack length $a$ mm	Stress Intensity Factor $K$ MPa $\sqrt{\text{m}}$								No hole	Open hole			
	Bonded Rivet												
	$t = 0.0127 \text{ mm}$		$t = 0.0254 \text{ mm}$		$t = 0.0508 \text{ mm}$								
	A	B	A	B	A	B							
0.5	9.1	12.1	10.6	14.2	12.7	16.9	-	-	-	25.6	-		
0.9	11.3	15.0	12.8	16.9	14.8	19.5	-	-	-	27.8	-		
1.5	14.3	18.4	-	-	-	-	-	-	13.1	29.9	-		
2.0	15.9	20.1	-	-	-	-	-	-	14.8	30.9	-		
2.6	17.1	21.4	-	-	-	19.8	-	-	16.0	32.1	-		

A = No adhesive failure.

B = Partial debonding of adhesive.

TABLE 3

Stress Intensity Factors for Specimen No. 1 Cracked on Both Sides,  $t = 0.0127$  mm

Crack length $a$ mm	Stress Intensity Factor $K$ MPa $\sqrt{m}$		
	Unfilled hole	Bonded Rivet	Bonded Rivet— Partial debonding of adhesive
0.5	26.4	9.1	12.2
0.9	29.7	11.3	15.3
1.5	33.9	14.5	18.8
2.3	39.2	17.6	22.6

TABLE 4

Stress Intensity Factors for Specimen No. 2 Cracked  
on One Side with Bonded Rivet,  $t = 0.0254$  mm

Crack length $a$ mm	Stress Intensity Factor $K$ MPa
1.0	12.9
1.8	16.0
3.0	20.2
4.0	22.5
4.6	24.2

TABLE 5

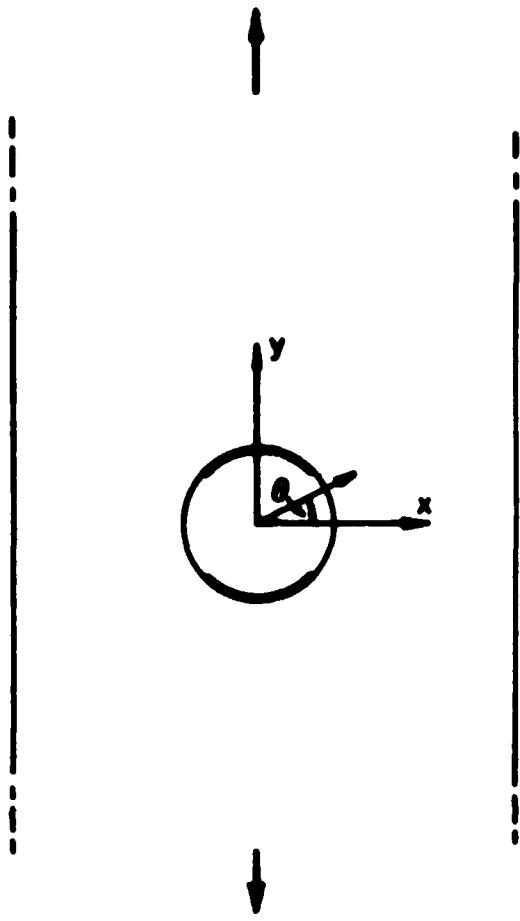
Stress Intensity Factors for Specimen No. 2 Cracked on One Side,  
 $t = 0.0254$  mm

Crack length $a$ mm	Stress Intensity Factor $K$ MPa $\sqrt{m}$	
	Bonded steel sleeve	Bonded sleeve— Partial debonding of adhesive
1.0	13.35	16.3
1.8	16.5	20.3
3.0	20.7	25.3
4.6	26.0	28.9

TABLE 6

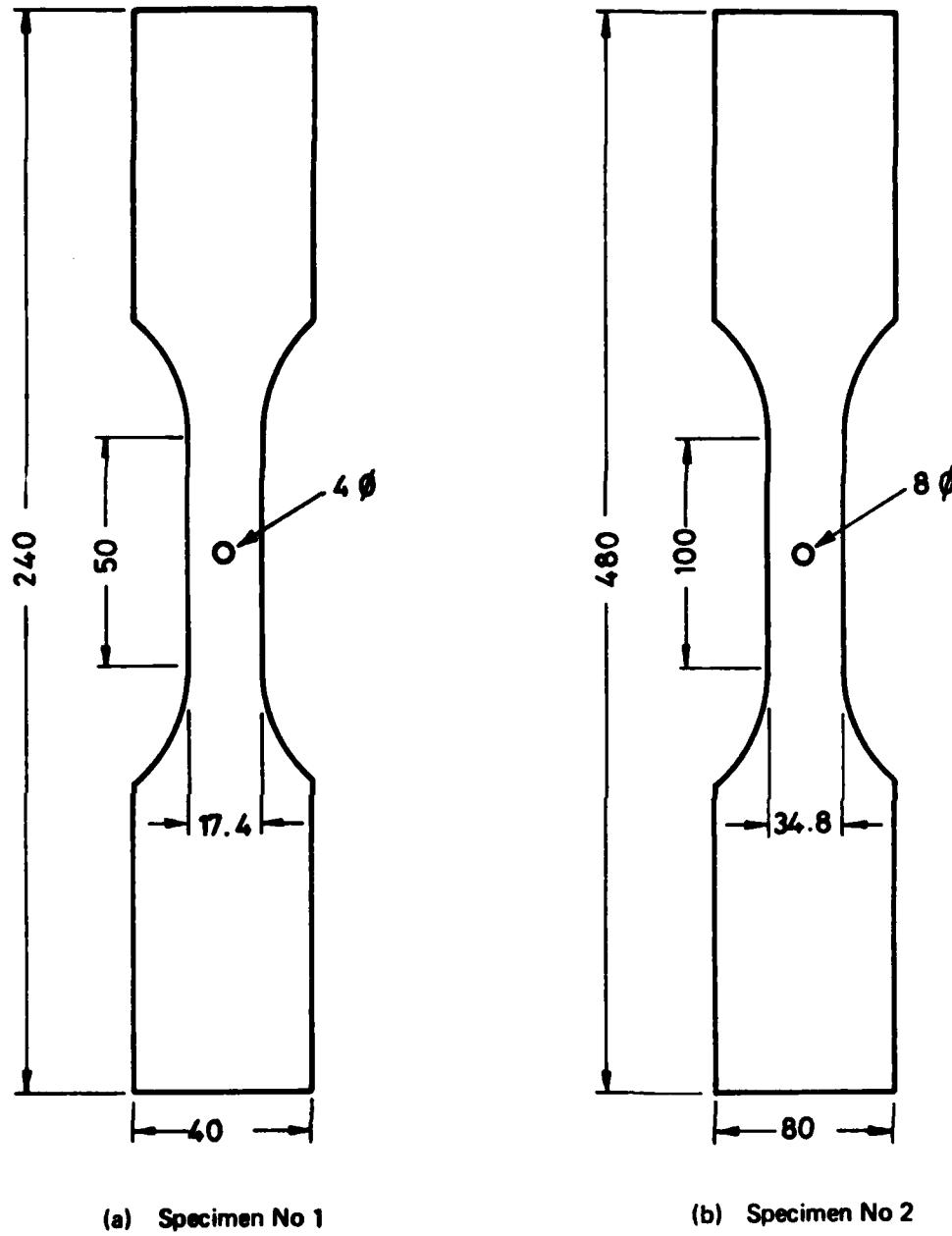
Experimental Fatigue Test Results for  
Specimen No. 1

Specimen Condition	Fatigue life (flights)
Open hole	5929
Cold worked open hole	8212
Hole with bonded rivet	15688



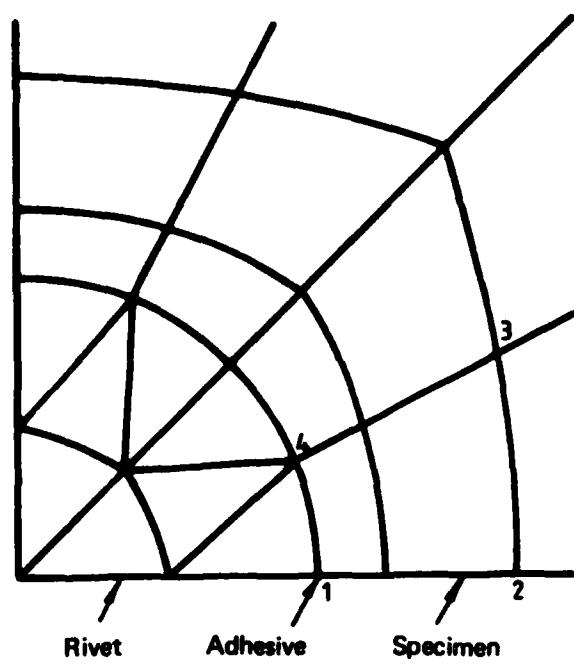
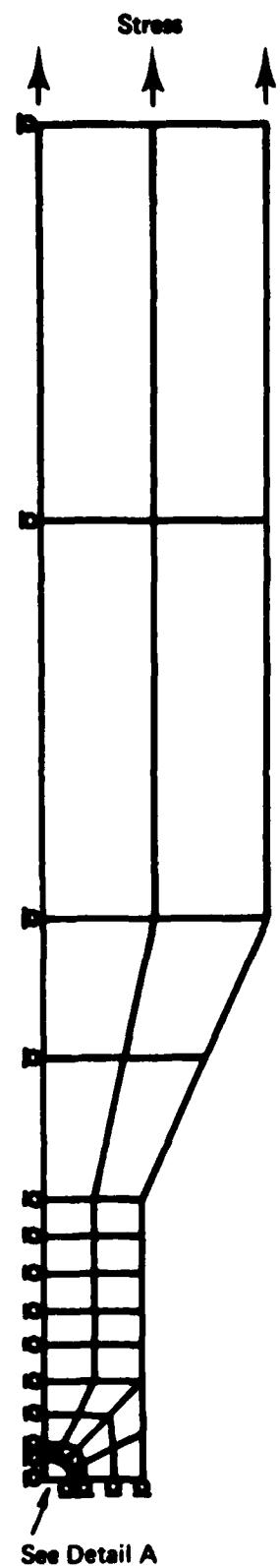
Debonding between;  $45^\circ < \theta < 135^\circ$  and  $225^\circ < \theta < 315^\circ$

FIG. 1 DEBONDED REGION FOR ADHESIVE FAILURE ANALYSIS



All dimensions in mm

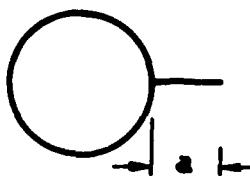
FIG. 2 DIMENSIONS FOR SPECIMENS 1 AND 2



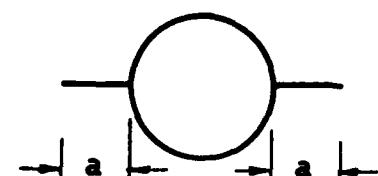
Detail A

FIG. 3 FINITE ELEMENT MESH FOR SPECIMEN NO.1  
UNCRACKED WITH BONDED RIVET

$a$  = Crack length

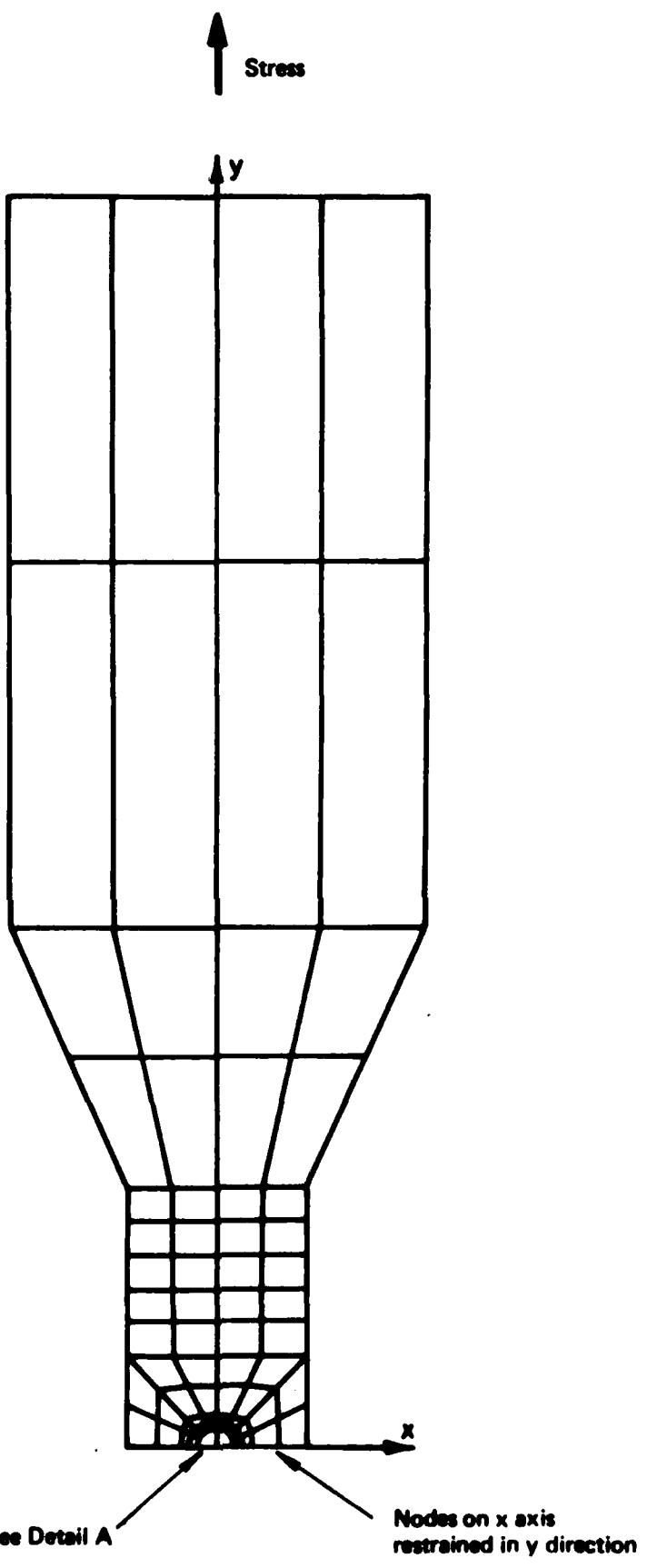


(a) Specimen cracked on  
one side only



(b) Specimen cracked on  
both sides

FIG. 4 CRACK GEOMETRY CASES



**FIG. 5(a) FINITE ELEMENT FOR SPECIMEN NO. 1 CRACKED ON ONE SIDE WITH BONDED RIVET**

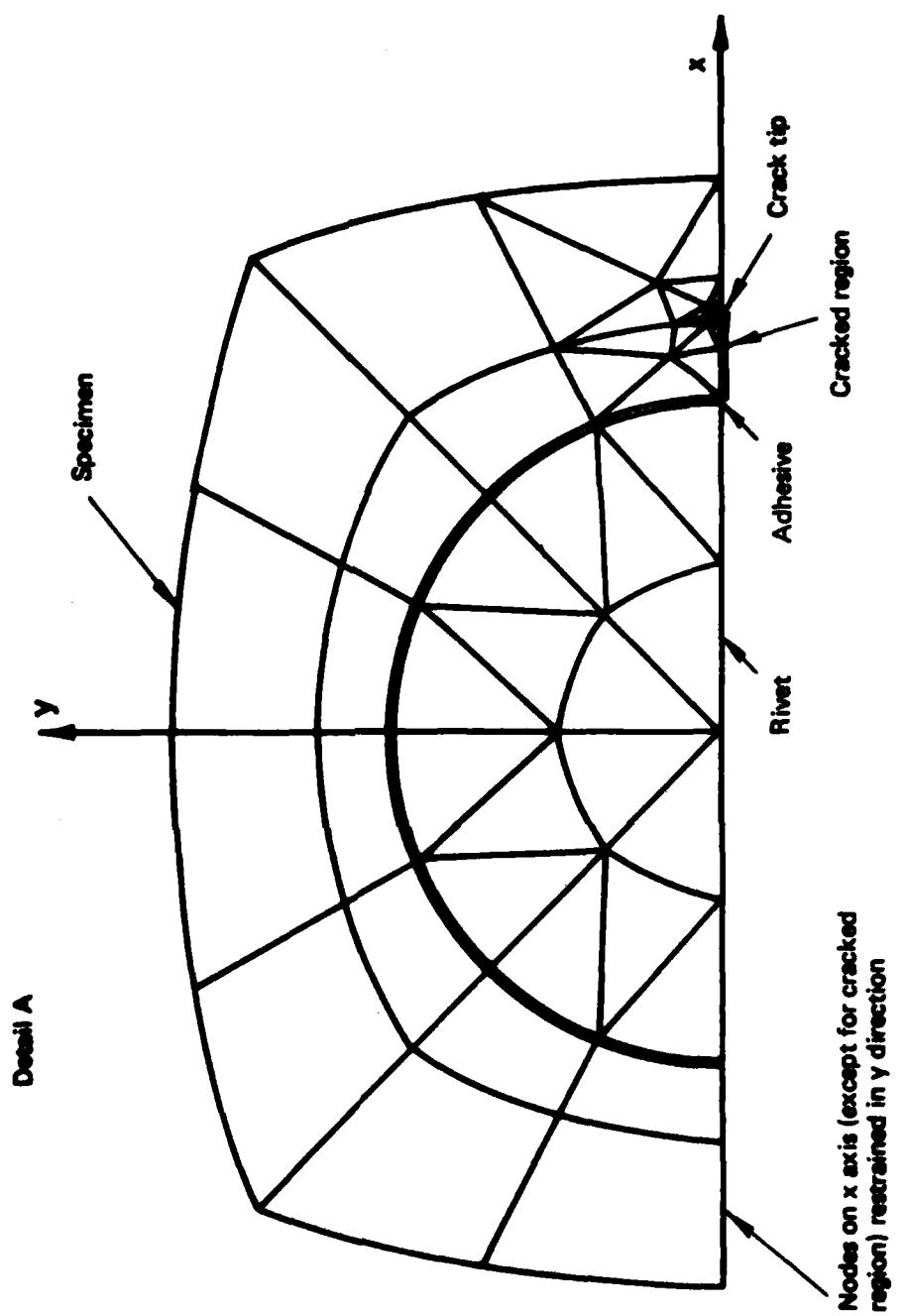


FIG. 5(b) FINITE ELEMENT MESH FOR SPECIMEN NO 1 CRACKED ON ONE SIDE WITH BONDED RIVET

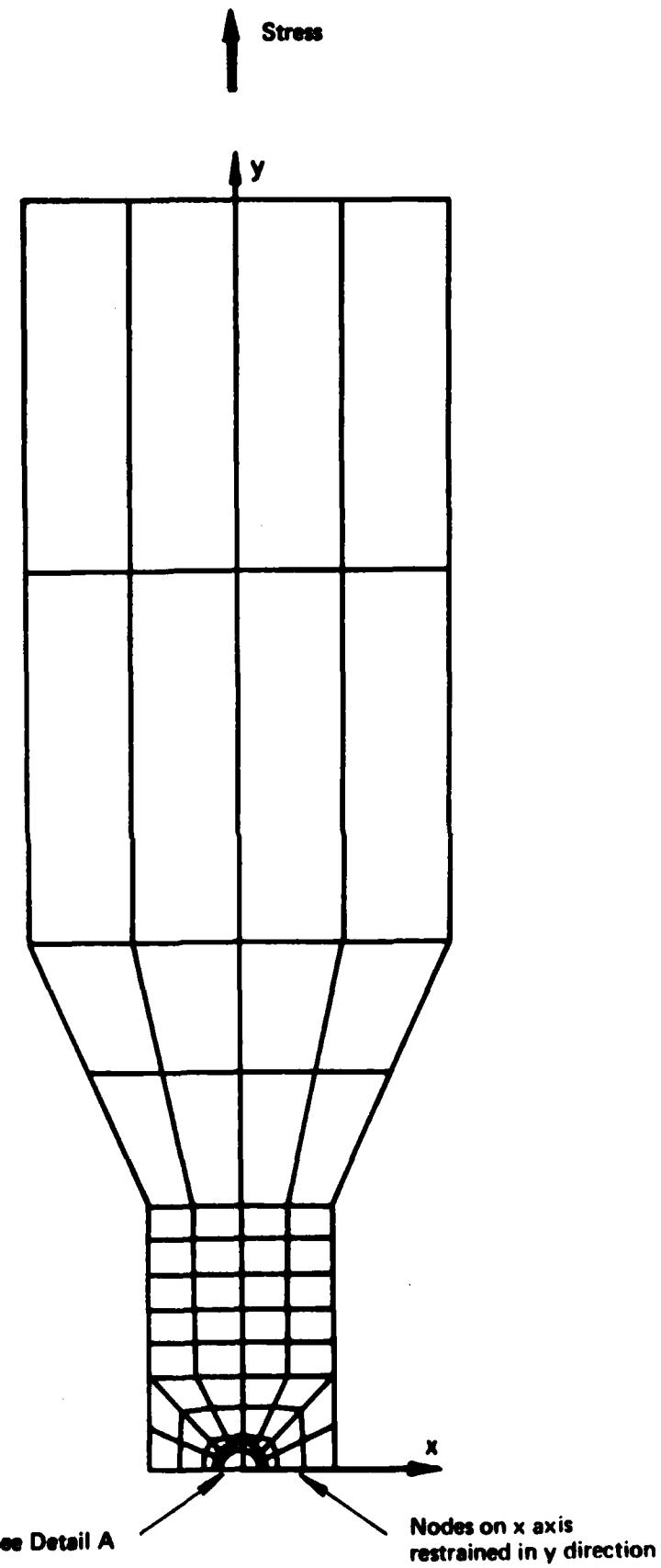


FIG. 6(a) FINITE ELEMENT FOR SPECIMEN NO 2 CRACKED ON ONE SIDE  
WITH BONDED RIVET

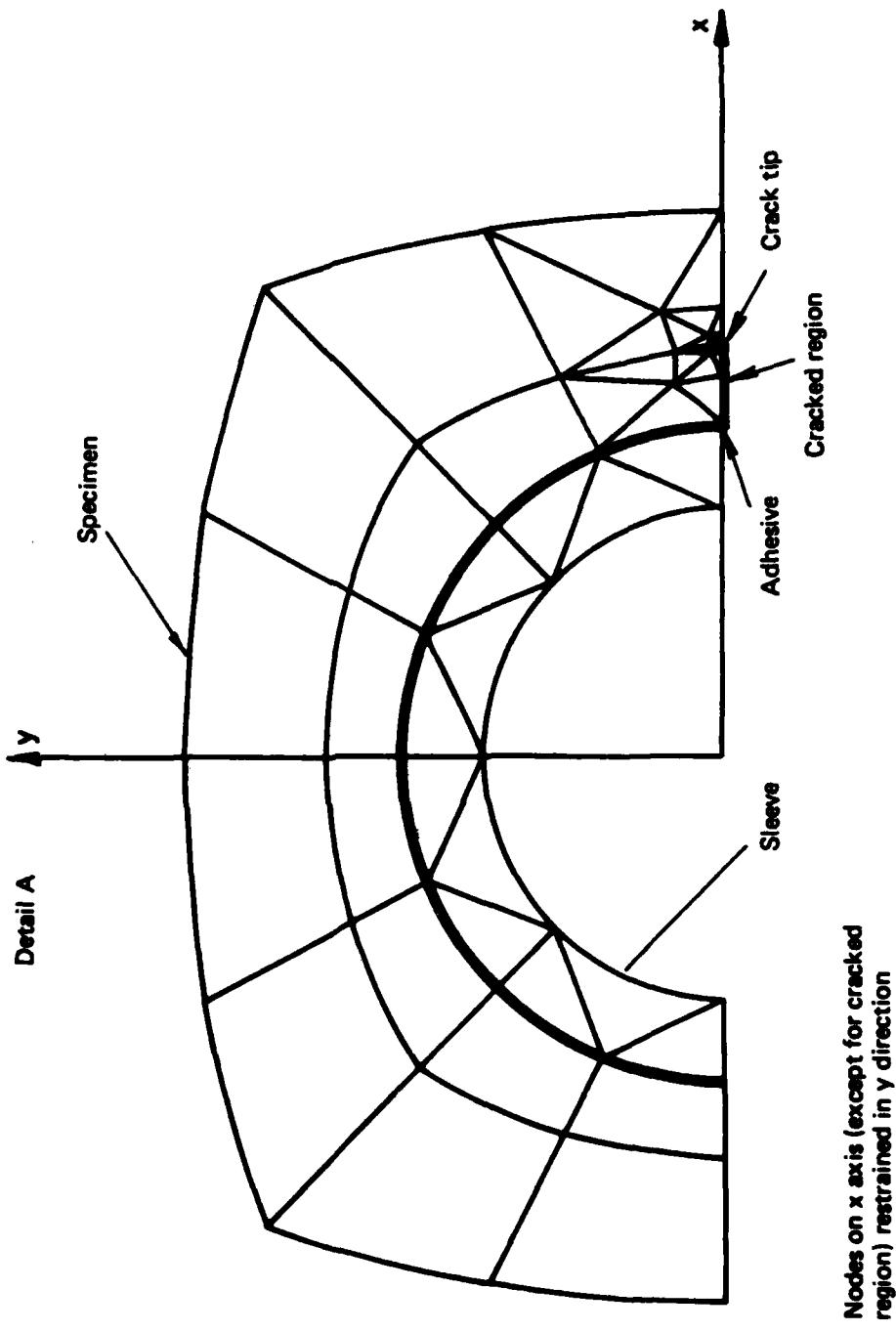


FIG. 6(b) FINITE ELEMENT MESH FOR SPECIMEN NO 2 CRACKED ON ONE SIDE WITH BONDED SLEEVE

## DISTRIBUTION

### AUSTRALIA

#### DEPARTMENT OF DEFENCE

##### Central Office

Chief Defence Scientist  
Deputy Chief Defence Scientist  
Superintendent, Science and Program Administration  
Controller, External Relations, Projects and Analytical Studies Division  
Defence Science Adviser (U.K.) (Doc. Data Sheet)  
Counsellor, Defence Science (U.S.A.) (Doc. Data Sheet)  
Defence Central Library  
Document Exchange Centre, D.I.S.B. (18 copies)  
Joint Intelligence Organisation  
Librarian, H Block, Victoria Barracks, Melbourne  
Defence Science Representative, Bangkok  
Director General—Army Development (NSO) (4 copies)

} (1 copy)

##### Aeronautical Research Laboratories

Director  
Library  
Divisional File—Structures  
Authors: R. Jones  
M. Heller

##### Materials Research Laboratories

Director/Library

##### Defence Research Centre

Library

##### R.A.N. Research Laboratory

Library

**Navy Office**

**Navy Scientific Adviser**  
**Directorate of Naval Aircraft Engineering**  
**Directorate of Naval Aviation Policy**  
**Superintendent, Aircraft Maintenance and Repair**  
**Directorate of Naval Ship Design**  
**R.A.N. Tactical School, Library**

**Army Office**

**Army Scientific Adviser**  
**Engineering Development Establishment, Library**  
**Royal Military College Library**  
**U.S. Army Research, Development and Standardisation Group**

**Air Force Office**

**Air Force Scientific Adviser**  
**Aircraft Research & Development Unit**  
    **Scientific Flight Group**  
    **Library**  
**Technical Division Library**  
**Director General Aircraft Engineering—Air Force**  
**Director General Operational Requirements—Air Force**  
**HQ Operational Command (SMAINTSO)**  
**HQ Support Command (SLENGO)**  
**RAAF Academy, Point Cook**

**Central Studies Establishment**

**Information Centre**

**DEPARTMENT OF DEFENCE SUPPORT**

**Government Aircraft Factories**

**Manager**  
**Library**

**DEPARTMENT OF AVIATION**

**Library**  
**Flying Operations and Airworthiness Division**

## **STATUTORY AND STATE AUTHORITIES AND INDUSTRY**

**CSIRO, Materials Science Division, Library**  
**Trans-Australia Airlines, Library**  
**Qantas Airways Limited**  
**Gas & Fuel Corporation of Victoria, Manager Scientific Services**  
**SEC of Vic., Herman Research Laboratory, Library**  
**Ampol Petroleum (Vic.) Pty. Ltd., Lubricant Sales & Service Manager**  
**Ansett Airlines of Australia, Library**  
**B.H.P., Melbourne Research Laboratories**  
**B.P. Australia Ltd., Library**  
**Commonwealth Aircraft Corporation, Library**  
**Hawker de Havilland Aust. Pty. Ltd., Bankstown, Library**  
**Major Furnace & Combustion Engineers Pty. Ltd., Manager**  
**Australian Institute of Petroleum Ltd.**  
**Rolls Royce of Australia Pty. Ltd., Mr C. G. A. Bailey**

## **Universities and Colleges**

<b>Adelaide</b>	<b>Barr Smith Library</b> <b>Professor of Mechanical Engineering</b>
<b>Flinders</b>	<b>Library</b>
<b>Latrobe</b>	<b>Library</b>
<b>Melbourne</b>	<b>Engineering Library</b>
<b>Monash</b>	<b>Hargrave Library</b> <b>Professor I. J. Polmear, Materials Engineering</b>
<b>Newcastle</b>	<b>Library</b>
<b>New England</b>	<b>Library</b>
<b>Sydney</b>	<b>Engineering Library</b> <b>Head, School of Civil Engineering</b>
<b>N.S.W.</b>	<b>Physical Sciences Library</b> <b>Professor R. A. A. Bryant, Mechanical Engineering</b> <b>Professor G. D. Sergeant, Fuel Technology</b>
<b>Queensland</b>	<b>Library</b>
<b>Tasmania</b>	<b>Engineering Library</b>
<b>Western Australia</b>	<b>Library</b> <b>Associate Professor J. A. Cole, Mechanical Engineering</b>
<b>R.M.I.T.</b>	<b>Library</b> <b>Dr H. Kowalski, Mech. &amp; Production Engineering</b>

## CANADA

CAARC Coordinator Structures  
International Civil Aviation Organization, Library

Energy Mines & Resources Dept.  
Physics and Metallurgy Research Laboratories

## NRC

Aeronautical & Mechanical Engineering Library  
Division of Mechanical Engineering, Director

## Universities and Colleges

Toronto

Institute for Aerospace Studies

## CZECHOSLOVAKIA

Aeronautical Research and Test Institute (Prague), Head

## FRANCE

ONERA, Library

## INDIA

CAARC Coordinator Structures  
Defence Ministry, Aero Development Establishment, Library  
Gas Turbine Research Establishment, Director  
Hindustan Aeronautics Ltd., Library  
National Aeronautical Laboratory, Information Centre

## INTERNATIONAL COMMITTEE ON AERONAUTICAL FATIGUE

Per Australian ICAF Representative (25 copies)

## ISRAEL

Technion-Israel Institute of Technology  
Professor J. Singer

## **JAPAN**

**National Research Institute for Metals, Fatigue Testing Division  
Institute of Space and Astronautical Science, Library**

### **Universities**

**Kagawa University      Professor H. Ishikawa**

## **NETHERLANDS**

**National Aerospace Laboratory (NLR), Library**

## **NEW ZEALAND**

**Defence Scientific Establishment, Library  
RNZAF, Vice Consul (Defence Liaison)**

### **Universities**

**Canterbury      Professor D. Stevenson, Mechanical Engineering**

## **SWEDEN**

**Aeronautical Research Institute, Library  
Swedish National Defense Research Institute (FOA)**

## **SWITZERLAND**

**Armament Technology and Procurement Group  
F+W (Swiss Federal Aircraft Factory)**

## **UNITED KINGDOM**

**Ministry of Defence, Research, Materials and Collaboration  
CAARC, Secretary**

**Royal Aircraft Establishment  
Bedford, Library  
Farnborough, Dr G. Wood, Materials Department**

**Commonwealth Air Transport Council Secretariat**

**Admiralty Marine Technology Establishment  
Holton Heath, Dr N. J. Wadsworth  
St Leonard's Hill, Superintendent**

**National Gas Turbine Establishment  
Director, Pyestock North**

**National Physical Laboratory, Library  
National Engineering Laboratory, Library  
British Library, Lending Division  
CAARC Coordinator, Structures  
British Ship Research Association  
National Maritime Institute, Library  
Electrical Power Engineering Co. Ltd.  
GEC Gas Turbines Ltd., Managing Director  
Fulmer Research Institute Ltd., Research Director  
Motor Industry Research Association, Director  
Ricardo & Co. Engineers (1927) Ltd., Manager  
Rolls-Royce Ltd.  
Aero Division Bristol, Library  
Welding Institute, Library  
British Aerospace  
Hatfield-Chester Division, Library  
British Hovercraft Corporation Ltd., Library  
Short Brothers Ltd., Technical Library**

## **Universities and Colleges**

Bristol	Engineering Library
Manchester	Professor, Applied Mathematics
Nottingham	Science Library
Southampton	Library
Strathclyde	Library
Cranfield Institute of Technology	Library
Imperial College	Aeronautics Library

**UNITED STATES OF AMERICA**

**NASA Scientific and Technical Information Facility  
Applied Mechanics Reviews  
Metals Information  
The John Crerar Library  
The Chemical Abstracts Service  
Allis Chalmers Corporation, Library  
Boeing Company  
Mr W. E. Binz  
Mr J. C. McMillan  
Lockheed-California Company  
Lockheed Missiles and Space Company  
Lockheed Georgia  
McDonnell Aircraft Company, Library  
Nondestructive Testing Information Analysis Center**

**Universities and Colleges**

<b>Florida</b>	<b>Aero Engineering Department</b>
<b>Johns Hopkins</b>	<b>Professor S. Corrsin, Engineering</b>
<b>Iowa</b>	<b>Professor R. I. Stephens</b>
<b>Illinois</b>	<b>Professor D. C. Drucker</b>
<b>Massachusetts Institute of Technology</b>	<b>M.I.T. Libraries</b>

**SPARES (10 copies)**

**TOTAL (202 copies)**

Department of Defence  
DOCUMENT CONTROL DATA

1. a. AR No. AR-003-941	1. b. Establishment No. ARL-STRUC-R-407	2. Document Date July, 1984	3. Task No. DST 82/009
4. Title <b>ON THE STRESS ANALYSIS OF BONDED INSERTS</b>		5. Security a. document Unclassified b. state U.	6. No. Pages 13 c. abstract U.
		d. date U.	7. No. Refs 11
8. Author(s) R. Jones and M. Heller		9. Downgrading Instructions	
10. Corporate Author and Address Aeronautical Research Laboratories P.O. Box 4331, Melbourne, Vic., 3001		11. Authority (as appropriate) a. Sponsor b. Security c. Downgrading d. Approval	
12. Secondary Distribution (of this document) Approved for public release.			
Overseas enquirers outside stated limitations should be referred through ASDIS, Defence Information Services Branch, Department of Defence, Campbell Park, CANBERRA, ACT, 2601.			
13. a. This document may be ANNOUNCED in catalogues and awareness services available to ... No limitations.			
13. b. Citation for other purposes (i.e. causal announcement) may be (select) unrestrictive (or) as for 13 a.			
14. Descriptors Bonding strength Stress analysis Inserts Adhesive bonding	Fasteners Fatigue life	15. COSATI Group 13050 12010	
16. Abstract Recent experimental work has shown that adhesively bonded inserts can significantly increase the fatigue life of fastener holes. This paper concentrates on developing an understanding of the mechanisms which give rise to the observed increase in life. Cracked as well as uncracked fastener holes are considered. It is shown that both the stress concentration factors, and the stress intensity factors are significantly reduced by the use of either bonded rivets or bonded sleeves. It is also shown that the stress intensity factor, for a cracked hole repaired by a bonded insert, can be obtained by analogy with readily available solutions. Addit. de lignes : Abstract ; bonding strength ; finite element analysis ; fracture mechanics ; elastic wave analysis ; numerical analysis ;			

This page is to be used to record information which is required by the Establishment for its own use but which will not be added to the DISTO data base unless specifically requested.

16. Abstract (Contd)

17. Imprint  
Aeronautical Research Laboratories, Melbourne

18. Document Series and Number  
Structures Report 407

19. Cost Code  
216901

20. Type of Report and Period Covered

21. Computer Programs Used

22. Establishment File Ref(s)

**END**

**FILMED**

**6-85**

**DTIC**